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CONDITIONED SUPPRESSION OF VESTIBULAR NYSTAGMUS WITH VISUAL STIMULI

Richard D. Gilson, Charles W. Stockwell, and Fred E. Guedry, Jr.

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NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FLORIDA

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NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
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PENSACOLA, FLORIDA 32508

SUMMARY PAGE*

THE PROBLEM

Under some flight conditions vestibulo-ocular responses degrade visual performance, although such degradation can be overcome, partially at least, with practice. The purpose of the present experiment is to investigate conditions which influence vestibular nystagmus habituation, and to develop a practical short procedure for improving visual/vestibular suppression ratios and for measuring individual differences in these improvements.

FINDINGS

Repetitive visual suppression of vestibular nystagmus in two 5-minute habituation sessions produced significant declines in visually suppressed vestibular nystagmus. The results indicate that short habituation procedures can be effective in improving visual/vestibular suppression ratios and that such procedures may also be practical for assessing individual differences in this improvement. The visual task used with one group of subjects during two 5-minute habituation periods proved to be highly nauseogenic. While this task may prove adaptable as a means of assessing a form of motion sickness susceptibility, another visual task which was not nauseogenic appears favorable for assessing individual differences in the visual/vestibular suppression ratio.

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INTRODUCTION

It is well known that vestibular nystagmus is suppressed when a subject-fixed visual reference is in view and that, conversely, vestibular nystagmus is enhanced when a stationary reference is viewed by a subject who is moving. The functional significance of these visual-vestibular interactions is clear. Under the latter condition, nystagmus combined with active pursuit eye movements closely compensates for head movements during the slow phase, thus stabilizing the image on the retina for clearer vision. In the former condition, vestibular nystagmus is inappropriate for a stabilized retinal image. The eyes are driven by the vestibular reflex; yet, the target to be viewed is fixed relative to the subject. In this circumstance, blurring of vision may occur, and central mechanisms intervene to suppress the vestibular nystagmus.

Practical consequences of these effects have been elucidated by laboratory (2,3), field (1,6,7,21), and clinical (19) observations. Aircraft and spacecraft frequently induce vestibular stimulation while their control demands accurate monitoring of cockpit instruments. A number of conditions influence the degree to which performance might be influenced by this visual-vestibular interaction. Magnitude and frequency of vestibular stimulation (2,17), illumination levels and wavelength (11,12), the planes of rotation (3,18), and alcohol consumption (9,13) all have important influences.

Dodge (10) and Wendt (22) postulated that some portion of vestibular habituation is due to the conditioning of opposing-response tendencies, and several more recent experiments support this theory (14-16,20). The present study deals with the possibility that habituation or conditioned suppression of inappropriate nystagmus may be revealed in the course of a fairly short conditioning sequence.

Most investigators who have repeatedly induced nystagmus in the presence of visual stimuli have tested for habituation in the absence of vision (4,14-16). The difficulty in recording nystagmus when head-fixed targets are visible is that quite strong vestibular stimuli are needed to produce a nystagmus response that measurably overcomes central ocular controls. Marshall and Brown (20), however, employed sufficiently strong stimuli to elicit recordable nystagmus in the light. They found a response decline with repeated simultaneous exposure to strong vestibular stimuli and a visual fixation target. This suggests that conditioned visual suppression was taking place. However, because of possible differences in the arousal of subject groups (notably the control group had no arousal task during repeated rotation in the dark), it is possible that group differences were partially due to the differential arousal during the habituation period.

It is the purpose of this investigation to: a) assess the magnitude of the conditioned suppression with visual fixation; b) attempt to measure the effect on a visual performance task; and c) develop a practical short procedure for the determination of individual differences in the ability to improve visual suppression of inappropriate nystagmus.

PROCEDURE

SUBJECTS AND APPARATUS

Thirty young, male students from the Naval Aviation Schools Command volunteered as subjects.

The apparatus has been described in detail in an earlier report (12). The angular stimulus was provided by the Human Disorientation Device (HDD), programmed to oscillate about a vertical axis. Frequency and peak angular velocity of sinusoidal oscillation were 0.04 Hz and ± 120 deg/sec, respectively. The subject was strapped to a seat in the HDD capsule with his head supported in the vertical position close to the axis of rotation.

The subject's continued attention and fixation were maintained during testing by performance of a compensatory tracking task utilizing a cross-pointer indicator (ILS aircraft instrument). This task has been previously described by Benson and Guedry (3). A quasi-random signal deflected the vertical needle of the instrument while the subject attempted to continuously readjust the needle back to center by appropriate manipulation of the short joy-stick control. Only the cross-pointer face was illuminated within the darkened capsule. The instrument was positioned at a distance of 0.8 m in front of the subject with the luminance level of the pointers held at 0.05 mL.

Accuracy of the subject's performance of the tracking task was measured on a modulus error signal which was proportional to needle deviation integrated over successive 1-second periods.

Lateral eye movements were recorded by the conventional electro-oculographic (EOG) technique. The angular velocity of the slow phase components of the nystagmus was measured from the graphical records. Prior to and following each recording of nystagmus, a calibration of EOG was carried out by relating 10-degree voluntary displacement of the eyes with pen displacement on the record.

METHOD

Three groups of ten subjects each were designated, respectively, as the visual conditioning group (VC), the tracking conditioning group (TC), and the auditory conditioning group (AC). Prior to initial testing, all subjects were given a brief description of the type of motion they would experience and instructions on the compensatory tracking task, followed by 6 minutes of practice tracking without rotation.

Preconditioning testing consisted of starting rotation and recording nystagmus in the dark for 1 minute while mental alertness was maintained by the use of mental arithmetic (5,8). Then nystagmus was recorded in the light, with the tracking display illuminated, while the subject performed the tracking task.

After a brief rest, the conditioning sequence was started. All subjects were given two 5-minute periods of rotation separated by a 30-minute rest period. The visual-conditioned group (VC) was presented with a 15 x 15 matrix of numbers and told to add each column and row. The digits, 0.6 cm in height, of the matrix were printed on a 20 x 45 cm card that was placed over the tracking display. Illumination for this card was provided by the overhead light in the HDD. The auditory-conditioned group (AC) was required to add the same sequence of numbers, with the exception that the numbers were presented verbally, and at the end of the sequence the subject was required to answer. Manual control of the tape recording allowed the subject to pace himself. The tracking control group (TC) was required to continue the compensatory tracking task throughout the conditioning periods.

The post-conditioning test was a repetition of the pre-test, i.e., 1 minute of recording nystagmus in the dark while the subject was engaged in mental arithmetic and 1 minute of recording nystagmus with the cross-pointer display illuminated while the subject concentrated on the compensatory tracking task. All the subjects were instructed to continue the tracking despite any blurring that might occur and to strive for speed and accuracy in solving the arithmetic problems.

RESULTS

Although nystagmus was recorded for 1-minute periods, only 50 seconds of the record were scored, or that interval corresponding to two full cycles of rotation (each cycle being 25 seconds). Since oscillation produces both leftbeating and rightbeating nystagmus, only the absolute values of the nystagmus mean slow phase velocity throughout the cycle were used to compute the arithmetic means.

An average of results from the pre- and post-conditioning tests is shown in Figure 1 as a bar graph of slow phase velocity in the dark and with the display lighted (visual fixation). The hatched area designates the drop in mean slow phase velocity from pre-testing to post-testing for each group. The number in the hatched area indicates percentage decline. Nystagmus in the dark appeared to be reduced by an equivalent amount for the three groups. This reduction of approximately 22 percent is not uncommon for subjects exposed to repeated angular accelerations in darkness with continuous auditory alerting tasks (16, p A13-10).

Nystagmus recorded in the light, however, produced a different set of results. It is noted initially that there was approximately a tenfold order of magnitude decrease in nystagmus slow phase velocity in the light due to visual fixation. In the light there was also somewhat greater variability than in the dark in the amount of nystagmus between groups, although there seems to be some correlation between the relative response output in the dark and in the light for a particular group. Conditioning with visual stimuli, such as a matrix of discrete numbers, or with a tracking display, seems to be advantageous. Both the VC group and the TC group showed a significantly greater reduction ($p < .01$) by an analysis of variance in pre- to post-nystagmus slow phase velocity than

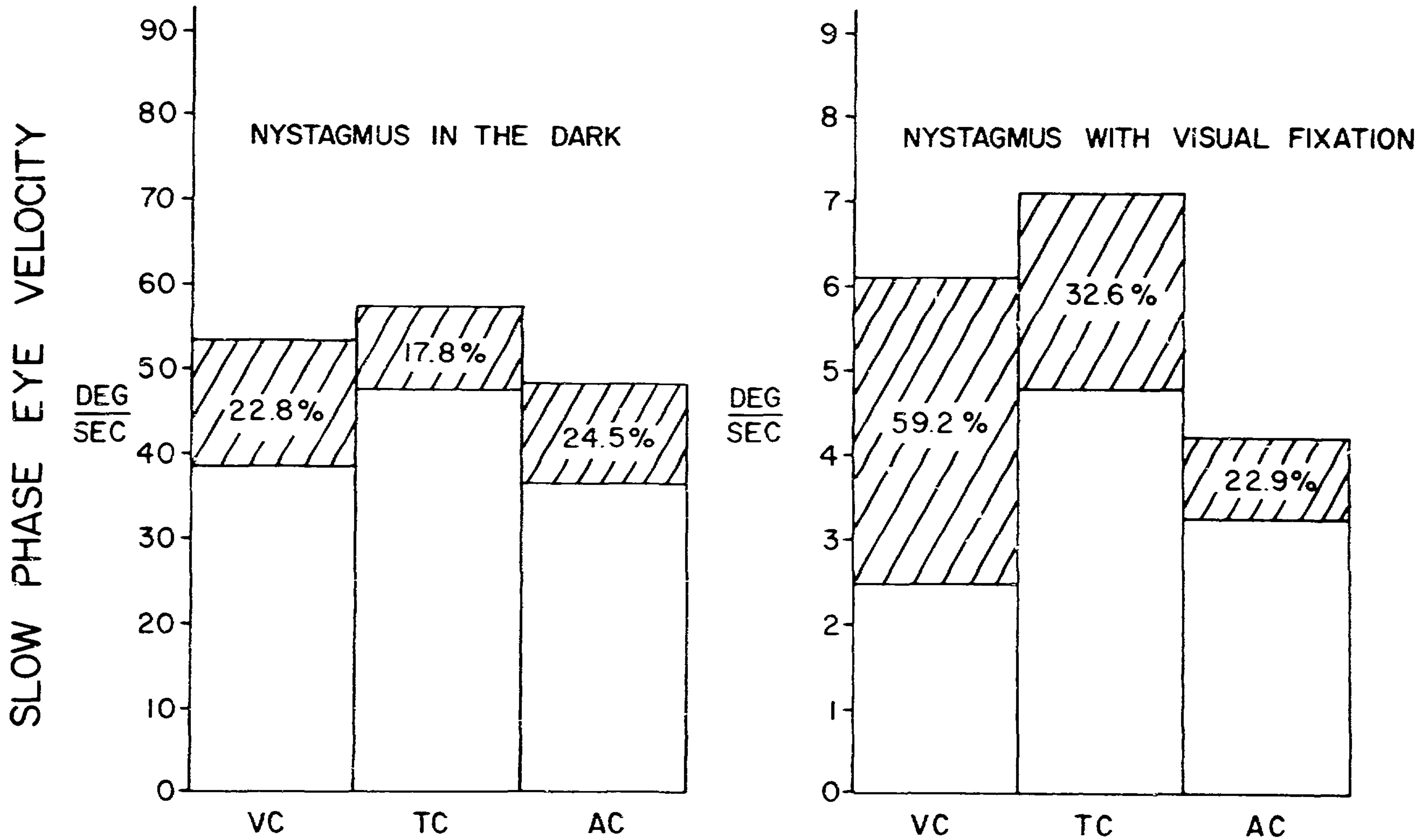

Figure 1

Mean slow phase velocity for pre- and post-conditioning tests. Hatched area represents pre- to post-reductions with the included percentage reduction. (VC) conditioning with visually presented numbers. (TC) conditioning with a compensatory tracking task. (AC) conditioning with an auditory presentation of numbers. Slow phase velocity on the abscissa refers to slow phase velocity averaged over the entire stimulus cycle.

did the AC group. Indeed, the AC group without visual conditioning showed about the same percentage reduction as all three groups when nystagmus was recorded in the dark.

A *t*-test also revealed a significant difference ($p < .05$) between the VC and TC groups. Thus, the type of visual stimulus may further determine the magnitude of conditioning, but in the present study this may have been due to a selection factor involving substantial motion sickness attrition in the VC group.

Since tracking performance was being recorded during nystagmus in the light, it was anticipated that there would be a corresponding reduction in tracking errors for the VC and AC groups. The TC group was not included in this comparison because of unequated practice effects occurring during the conditioning period. There was a significant decline in the group mean tracking errors, 21.8 percent for the VC group and 20.7 percent for the AC group, but these reductions were not significantly different ($p < .10$). Thus, tracking task results do not reflect the differential reductions found in nystagmus (i.e., 59.2 percent for VC and 22.9 percent for AC). This may be due in part to the high level of variance inherent in this tracking task, and also due to the fact that the visual tracking task can be adequately performed by maintaining cross-pointer orientation even when there is a distinct blurring of vision.

DISCUSSION

Reduction of appropriate nystagmus can be accomplished in alert subjects with and without vision during repetitive vestibular stimulation. However, visual tasks, and perhaps the particular task, VC versus TC, were important factors influencing the efficiency of conditioning. When a structured visual field is present, central ocular controls suppress the reflex to reduce the blurring. Since this has functional significance, suppression is enhanced with repeated exposures. After considerable exposure of subjects, reductions in nystagmus can be observed even when they are tested in the dark (14-16). Presumably this is a residual of the conditioned central control. In situations where nystagmus is always evoked in the dark, central ocular controls are meaningless, and reductions very likely occur because of other mechanisms. (For an overview of studies of vestibular habituation, cf. Ref. 8.)

The pre- to post-reduction of nystagmus in the light, 59.2 percent for VC and 32.6 percent for TC, brackets the 42 percent reduction found by Marshall and Brown (20), despite the fact that the visual stimuli and duration of stimulation in the two studies were somewhat different. This is a substantial improvement over the 22.9 percent reduction for the AC group, whose habituation program did not include visual stimuli.

The results for the AC control group in this study and the control group rotated in the dark by Marshall and Brown contrast markedly. The AC group in the present study showed about a 23 percent pre- to post-reduction of nystagmus during testing in the light. In the Marshall and Brown study, the control group, when tested in the light,

initially showed no decline and subsequently a 47 percent increase in nystagmus when the subjects were given an arithmetic alerting task.

The auditory task in the present study served to continuously elicit vestibular nystagmus during the conditioning interval. It is possible that either the amount of nystagmus elicited during this interval or some sort of adaptation to alerting tasks may account for the 23 percent pre-post decline in the present study as compared with no decline in other studies where continuous alerting in darkness was not attempted.

The active role of the subject may have played a role in the conditioning series. A greater participation in the visual task (VC) on the part of the subject perhaps results in stronger control over the reflex. Some insight as to the pervasiveness of appropriately channeled visual central controls over the vestibular reflex may be found in a series of studies by Gonshor and Melvill Jones (14), where the vestibulo-ocular reflex was altered to the extent of effecting substantial changes in stimulus-response phase relations. However, another explanation should be seriously considered in comparing the VC and TC groups. In our study a large proportion of subjects could not complete the experiment due to illness. Curiously, only those in the VC group became ill (8 out of 18 tested); not one subject in the TC group discontinued the experiment, even though they obviously had to maintain visual fixation. Evidently the greater opportunity for conflicting visual information with the interior of the HDD illuminated, or the complexity of the display itself, was sufficient to produce this difference. This may have influenced the difference between the VC and TC groups in regard to nystagmus habituation, in that with the VC group there was obviously a selection factor involved. Part of the procedures employed in this study, or perhaps a modification, may be suitable for selection and/or training of pilots in order to reduce inflight nystagmic interference. It is a relatively short and not necessarily stressful procedure. The tracking task is obviously more appropriate for training due to the avoidance of motion sickness problems.

Although the tracking task employed was apparently insensitive to the relative changes in nystagmus, unsolicited reports and postexperimental discussions with subjects indicated a greater reduction in the blurring in the VC group than in the AC group when the tracking task was re-introduced during the post-testing sequence. Further studies are being carried out to attempt to quantify this observation.

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Item 20. Abstract (continued).

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